

A Neural Network MODIS-CERES Narrowband to Broadband Conversion

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Introduction

Monitoring changes of radiative energy budget at top of the atmosphere requires satellite measurements with good instrument stability and very high accuracy. With climate monitoring in mind, improving instrument stability has been one of the most important objectives of CERES instrument designs. This study is aimed at assessing such instrument stability objectively by investigating the distributions of radiative fluxes from satellite measurements of well defined atmospheric objects. With months of CERES observations on TRMM and TERRA, we have developed a strategy to demonstrate the month-to-month stability of CERES instruments by studying the distributions of deep convective cloud albedos as well as outgoing longwave fluxes. Our study shows that both shortwave and longwave radiative flux distributions of CERES measurements for such objects are practically identical from month to month. It also shows very little differences among TRMM CERES, TERRA CERES FM1 and FM2.

This study also intends to provide an objective stability analysis of narrowband instrument, such as MODIS, in terms of energy budget. First, we develop a neural network model which performs MODIS narrowband radiances to CERES broadband radiance conversions. Then, we study the monthly mean flux distributions derived from the narrowband-broadband conversion. Collocated MODIS and CERES cross track scanning data are used for training the multi-level feed-forward back-propagating neural network model with special noise handling characteristics. Other information, such as theoretical radiative transfer calculations are adopted for improving the design of the neural network model as well as filling missing data at certain viewing angular geometry. Comparing with the conventional narrowband measurements -- atmospheric retrievals -- theoretical flux calculations procedure, the advantage of the neural network analysis is its ability to bypass various assumptions in the atmospheric retrievals as well as theoretical calculations.

Training Samples and Neural Network Models

The most relevant narrowband information to the broadband shortwave fluxes includes:

1. a visible channel, which indicates cloud optical thickness,
2. a near infrared channel, which indicates effective cloud particle sizes,
3. a longwave window channel for cloud temperature.

A visible channel at wavelength 0.65 micron is available both VIRS and MODIS. The near infrared channel at 3.7 micron wavelength, and the window channel at 11. micron are also available on both instruments. So, we will use these 3 narrowband channels as narrowband inputs.

To perform the narrowband-broadband conversions, we also need to know the geometry of the satellite and the sun. Such information includes solar zenith angle, viewing zenith angle and relative azimuth angle.

The output, broadband radiative fluxes, information comes from CERES shortwave (0.3 – 4 micron) and longwave (4 – 100 micron) observations.

With a processing orbit, TRMM provides us a 9 month of collocated narrowband (VIRS) -broadband (CERES) observations at a wide variety of viewing geometry. Theoretical narrowband calculations is performed at large viewing angles, since such observations are not available. These data is adopted in our study as the training samples.

A functional approximation neural network model (GRNN) is developed for the narrowband-broadband conversions. Mathematically, the approach is similar to previous narrowband-broadband conversion studies (e.g., Minnis et al., 1991). The analytic functional form is replaced by the neural network functional approximation in this study. General Regression Neural Network (GRNN) is a Nadaraya-Watson kernel regression. It is a normalized RBF network in which there is a hidden unit centered at every training case. These RBF units are called "kernels" and are usually probability density functions such as the Gaussian.

The hidden-to-output weights are just the target values, so the output is simply a weighted average of the target values of training cases close to the given input case. The only weights that need to be learned are the widths of the RBF units. GRNN is a universal approximation for smooth functions, so it should be able to solve any smooth function-approximation problem given enough data. Comparing with back propagating neural networks, GRNN can be trained instantaneously. But it requires more computations when applying it.

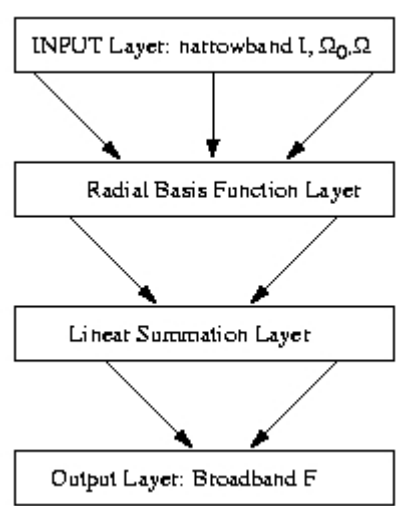


Figure 1generalized regression neural net

After the GRNN is trained from TRMM/VIRS and TRMM/CERES data, we applied the neural net to TERRA/MODIS narrowband data. The broadband planetary albedo derived from the MODIS to broadband conversion is compared with the broadband albedo derived from TERRA/CERES measurements. Figure 2 shows that the planetary albedo for deep convective cloud systems

(Tc<205K) derived from narrowband to broadband conversion with MODIS data matches the albedo derived from CERES broadband observations on TERRA.

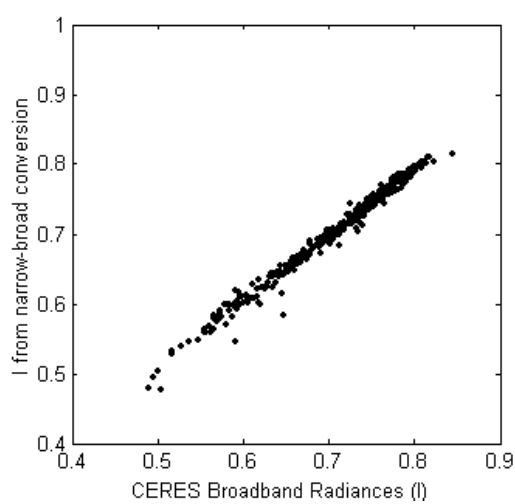


Figure 2: Planetary albedo comparison: MODIS narrowband–broadband conversion vs. CERES data from TERRA.

Distributions of Deep Convective Cloud System Planetary Albedo derived from Narrowband - Broadband conversion

Extensive, deep convective cloud systems reflect most visible light back to the space. The absorptions of near infrared energy by different systems are almost the same, because cloud particle microphysics, which determines absorptions, are similar. As a result, they are considered as a target for instrument stability monitoring.

To derive the planetary albedo from individual satellite measurements, the relationship between planetary albedo and bi-directional reflectance at specific solar and viewing geometry needs to be determined. It is decided by observations of similar atmospheric object at very different solar and viewing angles (Figure 3).

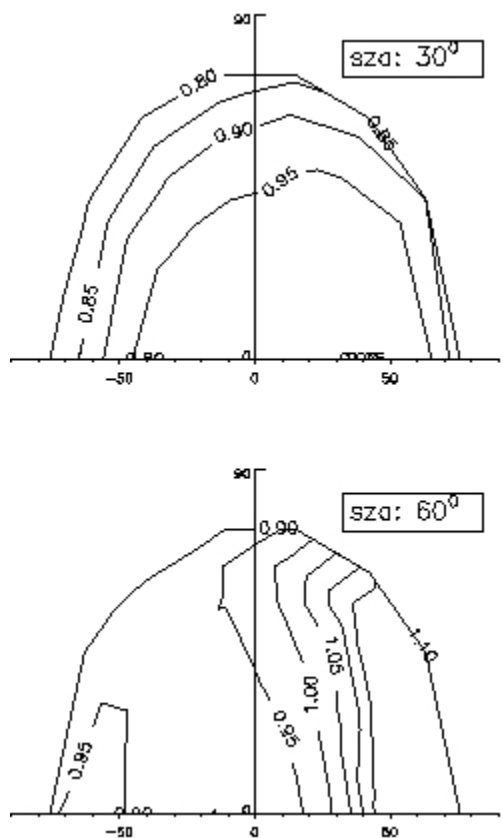


Figure 3: Reflectance to Planetary Albedo conversion factor. for solar zenith angles at 30 (upper panel) and 60 (lower panel) degrees.

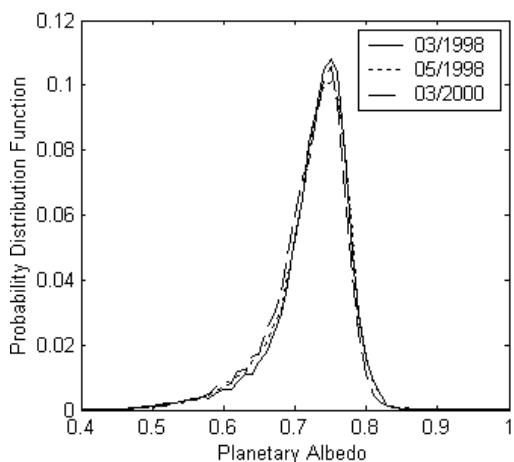


Figure 4: albedo probability distribution functions from TRMM/VIRS to broadband conversion

The distributions of planetary albedos of deep convective cloud systems from month to month have similar shapes and peak values. Figure 2 shows that the albedo distributions of 3 months (Mar. 1998, May 1998 and Mar. 2000) derived from VIRS narrowband to broadband conversion are almost the same (Figure 4). The peak albedos of these 3 months are 0.75. The distributions almost Gaussian-like, except with a long tail on the lower albedo side caused by the weak scene identification criteria ($T_c < 205$ K) which might have included some less reflecting clouds.

Applying the same neural nets derived from VIRS-CERES narrowband-broadband conversion to the MODIS data, we can also derive the planetary albedos for different months (Figure 5). The distributions for varies months are similar.

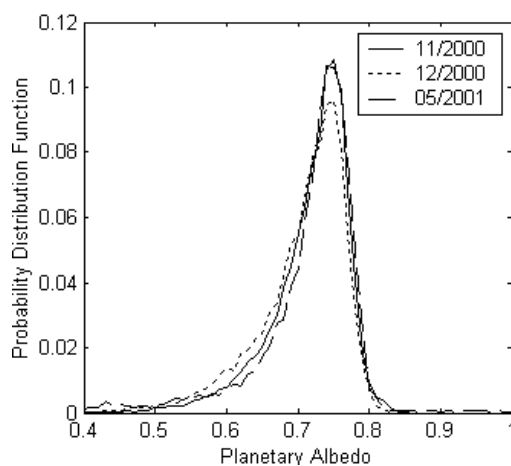


Figure 5: Albedo probability distribution functions from TERRA/MODIS to broadband conversion

The peak values are all around 0.75. Figure 5 indicates that MODIS narrowband instruments are stable. It also implies that the calibrations are consistent with VIRS instruments.

References

Minnis, P., D. Young and E. Harrison, 1991: "Estimation of the relationship between outgoing infrared window and total longwave fluxes using satellite data", **Journal of Climate**, vol. 4, no. 11, pp. 1114-1133.